Silurian, we find Emmons, in 1842, suggesting that the Taconic rocks in part might "be equivalent to the Lower Cambrian of Sedgwick," "the upper portion being the lower part of the Silurian System," to which the Middle and Upper Cambrian of Sedgwick were then, on the authority of Murchison, very generally referred. To repeat what we have already said, we add that this upper portion, the fossiliferous character of which he made known in 1844, was by Emmons declared, in 1860, to correspond to the Primordial of Barrande. "The upper part of the Taconic is equivalent to Barrande's Primordial zone," and again, "His Primordial group is *only Lower Silurian.* I conceive that we have exactly his *Primordial group* in the band of slates containing *Paradoxides.*"[1]

The names of Cambrian and Silurian were thus prior to that of Taconic, and so far as regards the Upper Taconic, it is now shown by palæontological studies to be unquestionably the stratigraphical equivalent of the great mass of the Cambrian of Sedgwick, including accidentally, as we have seen, small portions of his Upper Cambrian (Ordovician), but excluding, so far as yet known, the lowest Cambrian or Paradoxides horizon. It remains to be seen whether American or European geologists will abandon the accepted and well-defined terms of Cambrian for that of Taconic.

(To be concluded.)

NOTES ON THE GLACIATION OF THE PACIFIC COAST.

BY G. FREDERICK WRIGHT.

I HAVE elsewhere (see *Am. Jour. Sci.* for January) given an account of the results of my observations during last summer on the Muir Glacier, Alaska. The journey to and from that point of interest afforded equally good opportunities for observation.

The Northern Pacific Railroad passes out of the glaciated region at Sims' Station, Dakota, about forty miles west of Bismarck, at an elevation of two thousand two hundred and eighteen feet

[1] The italics are as found in the printed text.

above tide and three hundred and fifty above the Missouri River. The passage from the glaciated to the unglaciated region is quite marked and can easily be detected from the train. From this point on to the west no signs of glaciation appear until passing the western ridge of the Rocky Mountains near Lake Pend Oreille in Idaho. Here the movement was towards the west and was evidently local. Water-worn pebbles from this vicinity were observed far down in Eastern Washington Territory, in old water-courses, or "coulees," worn by post-glacial streams in the extensive lava deposits of that region.

West of the Cascade Mountains, between Portland and Seattle, all the streams coming down from Mount Rainier and its companions are heavily charged with glacial mud, and can be traced to extensive glaciers in the mountains. The White River Glacier, on the north side, is the largest of these. This glacier is from one to one and a half miles wide at its termination, which is about five thousand feet above tide. Two or three miles farther up it is about four miles wide. It is about ten miles long, and in its higher level merges in the general ice-cap which envelops the upper five thousand feet of the mountain. The height of the mountain is fourteen thousand four hundred feet.

The north and south valley between the Cascade Mountains and the Coast Range in Washington Territory is about one hundred miles wide. The northern half of this is penetrated by the innumerable channels and inlets of Puget Sound, which extends from Port Townsend south about eighty miles to the parallel of Mount Rainier. The Olympian Mountains to the west rise to a height of about ten thousand feet, as does Mount Baker in the Cascade Range to the northeast. The shores and islands of Puget Sound have every appearance of being a true glacial accumulation. No rock in place anywhere appears. The shores and islands rise from fifty to two hundred feet above tide, and present a mixture of that stratified and unstratified material characteristic of the terminal accumulations of a great glacier. Boulders of light-colored granite and of volcanic rocks are indiscriminately scattered over the surface and embedded in the soil. One of these boulders near Seattle, two hundred feet above the sound, was twenty feet in diameter and twelve feet out of ground. The channels of the sound and of the adjacent fresh-water lakes have a general north and south direction, parallel with the axis of the

valley. This is specially noticeable near Seattle, where Lake Washington, elevated sixteen feet above tide, and twenty-five miles long, is strictly parallel with the sound, and is separated from it by a series of ridges showing every mark of glacial origin. Not only is the surface of these ridges covered with boulders, but wherever the streets have cut down into the soil they show, at the depth of a few feet, an unstratified deposit abounding in striated stones. Superimposed upon this ridge there is a thin stratified deposit of varying depth but increasing in extent down the slope towards tide-water. At Port Townsend, on the Strait of Juan de Fuca, and forty miles north-northwest of Seattle, the coarsely stratified deposit is much greater in extent. A noteworthy section of this I had the privilege of studying at Point Wilson, two and a half miles northwest of Port Townsend. Here, facing the strait, is a perpendicular bluff from one hundred and fifty to two hundred feet in height, composed, in its lower portion, for about one hundred feet of rather fine, stratified material, which is capped at the summit by about fifty feet of coarse, unstratified material abounding in large striated boulders, which as they have been washed out by the erosion of the sea have fallen down to the foot of the bluff in immense numbers. Near the bottom of the bluff there are several strata of vegetable deposits. One of these, two feet thick, consisted almost wholly of the fragments of the bark of the fir-trees which are now so characteristic of that region. Fragments of wood project from the freshly exposed bank in great abundance. The meaning of these facts will be more readily apparent after a study of the phenomena to the north of the strait.

The Strait of Juan de Fuca is from fifteen to twenty miles in width, running east and west. Its north shore, near Victoria, on Vancouver's Island, is remarkably clear of glacial débris. The rocks, however, near Victoria exhibit some of the most remarkable effects of glacial scoring and striation anywhere to be found. Immediately south of Victoria long parallel furrows rise from the shore of the inlet and ascend the slope of the hill to the south to its summit, a hundred feet or more above the water-level. At the steamboat-landing, outside of the harbor, extensive surfaces freshly uncovered exhibit the *moutonnée* appearance of true glaciation, and, in addition to the finer and abundant scratching and striæ, display numerous winding furrows from six inches

to two feet in depth, and from twenty to thirty-two inches in width, and ten or more feet in length. These grooves are finely polished and striated, resembling those with which geologists are familiar on Kelly's Island, Lake Erie. Like the corresponding grooves on Kelly's Island, some of these also turn around the southern point in graceful curves, adjusting themselves to the retreating face of the rock-wall. That the motion of the ice here was to the south is evident not only from the direction of the striæ, but from the fact that the stoss side of the glaciated rocky projections are towards the north. That they are due to glacial action, and not to icebergs, is evident both from their character and from their analogy to numerous facts farther to the north, which are unquestionably connected with true glaciers.

Vancouver's Island, which trends parallel with the shore of the continent, northwest by southeast, is nearly three hundred miles in length, and from fifty to seventy-five in breadth. In character it seems but a continuation of the Coast Range of mountains, with numerous peaks rising from four to seven thousand feet above the sea. The shore-line of the continent upon the northeastern side of the Strait of Georgia is formed by a continuation of the Cascade Range, with a general elevation of from three to eight thousand feet, penetrated in numerous places to a distance of seventy-five miles by inlets or fiords several miles in width. Mr. George Dawson has described the glacial phenomena in Bute Inlet, which enters the Strait of Georgia about opposite the centre of Vancouver's Island, in latitude 50° 30′. He describes the chasm (see *Quarterly Journal of Geolog. Soc.*, vol. xxxiv. p. 89) as forty miles in length, surrounded by mountains, rising in some places in cliffs and rocky slopes from six to eight thousand feet. "The islands about its mouth are *roches moutonnées*, polished and ground wherever the original surface has been preserved."

The mountains on either side the Strait of Georgia, and northwestward to the head of Lynn Channel, in latitude 59° 20′, are snow-clad throughout the whole season. The shores are everywhere rocky and precipitous, retaining in many places far up their sides glacial striæ parallel with the direction of the numerous channels which thread their way through the Alexander Archipelago. I had opportunity at Loring, on the western shore of Revilla Gigedo Island, to examine minutely the striation on the shores and islands of the bay. There are now no glaciers

coming down from the mountains of this island, but the shores and islands abound in well-preserved glacial striæ running W. by 18° N., corresponding to the direction of the local valley down which the glacier came, and entering Behm's Canal nearly at right angles to its course upon that side of the island. This is in latitude 55° 40′.

Upon proceeding one degree to the north, I had opportunity also to observe closely the striæ at Fort Wrangell. Here, too, they show the influence of the continental elevation to the east, and are moving outward in a westerly direction towards the Duke of Clarence Strait. About thirty-five miles up the Stikine River, two glaciers are encountered of immense size coming down, one from the north and one from the south, to the vicinity of the vast cañon through which the river runs. The glacier from the north is about forty miles long and two miles wide near its mouth, spreading out to five miles a short distance back from the river, which it approaches to within four hundred yards. The glacier approaching the river at this point from the south is not so long and reaches only to within about two miles of the river. It is clear that a comparatively slight extension of these two glaciers would make them unite and close up the outlet of the river, and it requires no great stretch of the scientific imagination to see the whole valley occupied by a glacier, moving towards the ocean with an immense subglacial stream emerging at the ice front, wherever that might have been. From phenomena observed in Glacier Bay I am led to credit the tradition of the Indians that within historic times these glaciers met and the Stikine River made its way under them through an immense tunnel.

From the mouth of the Stikine River northwards, glaciers in great numbers and of great size are seen coming down from the mountains towards the sea-level, while all the mountains upon the islands are snow-clad through the whole summer, and some of them contain glaciers of small size. At Holcomb Bay and Taku Inlet glaciers come down to the sea-level and send off numerous small icebergs, which are frequently met with in Stevens' Passage. At the head of Glacier Bay no less than four glaciers of great size come down to tide-level, sending off immense numbers of small fragments and bergs. The evidence here of the recent vast extension of these glaciers down the bay, and of the facility of glacier-ice in adjusting itself to the local

topography, is of a most explicit and interesting character. The Muir Glacier, which is two miles wide at its mouth, is formed by the confluence of nine main streams, coming in majestic curves from the southeast, east, north, northwest, and west, and uniting in a vast amphitheatre of ice many miles in diameter a short distance above its present outlet. From the surface of this icy amphitheatre numerous islands project, as from the waters of an archipelago. The summits of these bear every mark of having been freshly uncovered by the decreasing volume of ice. Below the mouth of the glacier numerous islands in the bay present exactly the same appearance, except that they now project from water instead of ice. Their recent glaciation is indicated by every characteristic sign. Willoughby Island, about the middle of the bay, is as much as a thousand feet above the water. Were the ice to retreat a few miles farther, it would doubtless uncover an extension of the bay with numerous islands similar to those now dotting its surface south of the glacier. Fresh glacial débris lingers on the flanks of the mountains on either side of the inlet at a height of two thousand feet; and at three thousand seven hundred feet striæ were observed moving, not down the mountain, but parallel with the axis of the bay, showing that the present glacier is but the remnant of an ice-flow of similar character and direction of movement, but of vastly greater dimensions, extending and filling the whole bay to its mouth in Cross Sound, a distance of twenty-five miles. At Sitka the rocks in the harbor are all freshly striated, the direction of the movement being in a westerly direction, or towards the open sea. Glaciers still linger in the mountains at the head of the bay to the east of Sitka.

From all these facts it seems evident that we have only to suppose a slight increase of present forces favorable to the production of glaciers to find a state of things which will account for all the facts and unravel the whole intricate web of phenomena upon the western coast of North America.

The present formation of glaciers on the coast of Southeastern Alaska is favored not so much by the coolness of the climate as by the elevation of the mountains and the excessive amount of precipitation, which is not far from one hundred inches annually. There is no evidence that the elevation of the coast has materially changed in recent times. Nor is there evidence of any changes

in the amount of precipitation. It would only be necessary to suppose a slight diminution of temperature to secure all the additional force required to extend the present glaciers of Southeastern Alaska, British Columbia, and of the Cascade Range in Washington Territory and Oregon, until they should occupy all the channels of the Alexander Archipelago, fill the space occupied by the Strait of Georgia between Vancouver's Island and the main-land, and cover the whole valley between Mount Rainier and the Olympian Mountains, where now we find the vast moraine deposits of the islands and shores of Puget Sound. Southward, in Oregon, the Willamette valley is filled in a similar manner by an extension of the glaciers still lingering on the flanks of Mounts Hood and Shasta. The absence of drift on the southern shore of Vancouver's Island seems to point to a termination of the northerly movement in the Strait of Juan de Fuca, where, perhaps, the confluent streams turned westward and sent off vast drift-laden icebergs to the sea. Mount Baker, immediately to the east of this point, is upwards of ten thousand feet high, and still preserves glaciers on its flanks, and would have aided greatly in this movement.

In the boulders about Puget Sound, and in the striated surfaces which must exist somewhere in the vicinity, there is doubtless positive evidence of the direction of the ice movement which brought to its present position the immense ridges and piles of glacial débris forming the fertile soil of this remarkable region. It is to be hoped that local observers will not long leave the world in doubt as to the source of the boulders and the direction of the striæ about Puget Sound. To me the shores and islands of that region had the appearance of being the terminal deposits of confluent glaciers coming down from the flanks of Rainier to the southeast, and from the lower portions of the Cascade Range farther north, joined by smaller glaciers from the Coast Range on the west. It is clear that the earlier glacial movements on the Pacific coast were local in character, and must be studied independently of those east of the Rocky Mountains. The ancient glaciers of the Pacific coast can be understood only by reference to the glaciers which still linger at the head of all its numerous valleys, inlets, and fiords. In these the investigator has his *vera causa* ever before his eyes to guide his steps and to assist his imagination.